



**Geotechnical
Environmental and
Water Resources
Engineering**



Western Surface Water Drainage Project

Waimanalo Gulch Sanitary Landfill
Ewa, Oahu, Hawaii

Submitted to:
Waste Management
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1.0 Purpose and Description

The purpose of this project is to prepare a design for Phase III of the Western Surface Water Drainage Project at the Waimanalo Gulch Sanitary Landfill. The project will control and divert storm water run-on around the landfill area. The Western Surface Water Drainage Project includes a drainage diversion structure and rock channel at the upstream portion that transitions to a buried fiberglass polymer mortar pipe. The termination of the Western Surface Water Drainage Project will include a downstream discharge point with a flip bucket and new stilling basin (flip bucket and plunge pool) to dissipate the water energy from the pipe, and allow for more manageable discharge velocities in the existing spillway channel. The Western Surface Water Drainage Project will convey storm runoff separately from drainage from the landfill area. Storm runoff from the Western Surface Water Drainage Project will be routed towards the existing culverts under the Farrington Highway, bypassing the existing sedimentation basin which would then receive only affected runoff from the landfill.

A future report will present additional design details for the Phase III downstream terminal structures, and will also present design details for a proposed 36" HDPE temporary stormwater diversion to convey run-on flows upstream of Municipal Solid Waste Cell E6 to a downstream discharge point in the existing Phase II channel extension.

The Design of Phase III of the Western Surface Water Drainage Project for the Waimanalo Gulch Sanitary Landfill is being performed for Waste Management by GEI Consultants, Inc. (GEI), of Oakland, California in coordination with Geosyntec Consultants, Inc.

2.0 Project Location and Background Information

The Waimanalo Gulch Sanitary Landfill is located on the south-west side of Oahu, Hawaii, about 13 miles west of Pearl City along Farrington Highway. A location map is provided on Drawing C-00.

Several studies of various phases of project development have been made earlier for the City and County of Honolulu. These earlier studies along with the Phase III design studies are discussed below.

- Phase I Design: Waimanalo Gulch Sanitary Landfill Phase I Design was prepared for the City and County of Honolulu in 1986 by Shimabukuro, Endo Yoshizaki, Inc. The project included facilities for handling sanitary landfill and surface runoff drainage to reroute and convey 2750 cfs design flow collected from a catchment area of 622 acres. The drainage channel was 1850 feet long and conveyed supercritical flows. A stilling basin and a sedimentation pond with two (2) 48-inch-diameter riser-pipe outlets were provided at the downstream end of the channel.
- Phase II Design: Waimanalo Gulch Sanitary Landfill Drainage Channel Extension Phase II Design was prepared for the City and County of Honolulu in 1991 by Kwock Associates, Inc. The Phase II project extended the drainage system in conjunction with planned expansion of the sanitary landfill to the north up the gulch. The Phase II surface runoff drainage extension channel branched off from the existing Phase I drainage channel at Sta. 7+50 on an alignment that turned slightly westward with a steeper slope that traveled along higher ground to end at an inlet located at Sta. 41+93. The Phase II drainage channel extension had a capacity of 2500 cfs at the upstream end and 2750 cfs at the downstream end.
- Phase III Preliminary Design: Preliminary design of the Western Surface Water Drainage Project (Western Perimeter Drainage Extension) was initiated in 2006 by GEI for Waste Management for support of a landfill expansion permit application.
- Phase III Permit Design: The current design report in this report supersedes the Western Surface Water Drainage Project Design was prepared for Waste Management in 2008 by GEI. The Permit Design documents for the landfill expansion permit application include this Design Report and the associated Drawings (C-01 to C-15 and C-21 to C-23). The Western Surface Water Drainage Project is required to divert the 25-year storm event run-on collected from the drainage basin formed by the upper part of the Waimanalo Gulch located north of the landfill and convey the stormwater flow around the landfill. The Western Surface Water Drainage Project is also designed to convey the 100-year storm event run-on from the same basin and will divert the storm flows around the west and north foot-print of the sanitary landfill.

The main conveyance components of the project from the upstream to downstream end are presented on Drawings C-02 to C-07 and are as follows:

1. A concrete diversion structure to intercept flows from Waimanalo Gulch
2. An excavated rock channel approximately 1,080 feet long
3. A concrete box culvert transitional structure, approximately 160 feet long
4. A buried fiberglass mortar pipe (HOBAS pipe) conveyance with diameters varying from 102" to 78", total length approximately 5,200 feet
5. A new stilling basin (flip bucket and plunge pool) at the downstream end of the pipeline that discharges to the existing spillway channel and Farrington Highway culverts. The location of the flip bucket and plunge pool will be approximately 250 feet upstream of the Farrington Highway culverts.

The total elevation gain of the conveyance system is about 640 feet for an overall grade of about 9.8 percent. From approximate Station 16+80 to 26+55 (Refer to Drawing C-04) the fiberglass mortar pipe conveyance will be placed in the existing Phase II drainage channel, and this area will be backfilled to allow for temporary stockpile placement for landfill operations.

- Phase III Design Implementation: Construction of the Western Surface Water Drainage Project is planned to progress in an uphill direction starting from the downstream exit point from the existing drainage channel (approximate Station 12+00, Drawing C-04). The installation of the upstream segment of the design (Station 12+00 to Station 66+00), will allow for conveyance of stormwater flows beneath the proposed stockpile area depicted on Drawings C-04 and C-05. This upstream pipeline segment will be tied into the downstream pipeline segment from Station 12+00 to the flip bucket and plunge pool area to complete the downstream termination and discharge of the western perimeter flows.

At the upstream end of each stage of Western Surface Water Drainage Project construction, a temporary excavated channel will be constructed to divert and convey storm flows into the constructed portion of the new channel and pipeline. Currently, the West Stability Berm has been extended to bury an approximately 1,100 foot length of the Phase II drainage channel upstream of Sta. 27+00. Also, temporary landfill stockpiling operations will cover an additional 1,020 feet of Phase II drainage channel downstream of Station 27+00.

Two 48-inch diameter corrugated metal pipes (CMP) have been installed beneath the West Stability Berm to convey stormwater flows from northeastern upstream drainage areas into the Phase II channel while the sanitary fill placement continues over the existing channel. For future conveyance of these upstream drainage areas beneath the west berm and temporary stockpile fill areas, there will be a 36" diameter HDPE temporary diversion pipe that will convey stormwater flows upstream of the proposed Municipal Solid Waste Cell E6 area to the existing Phase II channel downstream of the temporary stockpile (approximately 1,600 feet upstream of Farrington Highway). The 36" diameter HDPE temporary diversion pipe will be inserted into the east existing

CMP and the west CMP will be abandoned by capping at the upstream and downstream ends.

After the downstream end of the 36" HDPE pipe exits the CMP, it will be placed next to the Western Surface Water Drainage Pipe in the existing channel and backfilled as shown on Drawing C-20. The downstream portion of the Phase II channel will be preserved to convey discharge for the temporary diversion pipe and the interior landfill drainage to the existing sedimentation and stilling basin.

Additional information and design details for the temporary diversion and the new stilling basin (flip bucket and plunge pool) for the Western Surface Water Drainage Project will be presented in a subsequent report.

3.0 Previous Studies and Supporting Design Information

3.1 Previous Studies

GEI relied upon the following available engineering information and data for preparation of the Western Surface Water Drainage Project design.

Aerometric, 2009, Digital Topographic Map of Waimanalo Gulch Sanitary Landfill Expansion, Oahu, Hawaii, Prepared for Waste Management, Inc., March 16.

GeoSyntec Consultants, Inc., 2008, Digital Topographic Map of Waimanalo Gulch Sanitary Landfill Expansion, Oahu, Hawaii, Prepared for Waste Management, Inc., May 9.

GeoSyntec Consultants, Inc., 2007, Hydrologic Analysis for Waimanalo Gulch Sanitary Landfill Expansion, Oahu, Hawaii, Prepared for Waste Management, Inc.

Geolabs, Inc., 2000, Geotechnical Engineering Services, Temporary Construction Cut Slope, Waimanalo Gulch Sanitary Landfill, Ewa, Oahu, Hawaii, Prepared for Waste Management, Inc., August 18.

Geolabs, Inc., 2003, Cut Slope Design, Waimanalo Gulch Sanitary Landfill, Ewa, Oahu, Hawaii, Prepared for Waste Management, Inc., February 24.

Kwock Associates, Inc. Consulting Engineers, 1991, Waimanalo Gulch Sanitary Landfill Drainage Channel Extension, Prepared for Waste Management, Inc., March.

3.2 Supporting Design Information

General Design Basis: The project design will be in general accordance with Waste Management project requirements, City and County of Honolulu guidelines, and based on the results of meetings between representatives of Waste Management, GeoSyntec Consultants, and GEI. Drawing C-02 shows the general layout of the project main features.

Survey Stationing: Stationing of the new Western Surface Water Drainage conveyance alignment is based on stationing established by Geosyntec (2008) and begins at the culverts under Farrington Highway and increases northward up the gulch.

Hydrology: Hydrologic analyses were completed by Geosyntec Consultants in 2007 for the 1.1 square mile drainage basin and peak flows corresponding to 2, 5, 10, 50, and 100-yr

storm events were computed. Based on this study, the computed 100-year, 24-hr storm peak flow run-on from upstream areas of the gulch into the Western Surface Water Drainage channel diversion structure is 1751 cfs and the 25-year design storm is 1135 cfs. The design flood used for sizing the Western Surface Water Drainage conveyance structures between Station 26+50 and 67+58 is 1,751 cfs.

Geology: Based on the two available geology reports (Geolabs, Inc., 2000 and 2003) and also other sources of information, Waimanalo Gulch is situated upon interlayered basalts, with localized Quaternary sedimentary deposits or soils primarily found on ridge top areas. The basalts originate from the volcanic Wai'anae Mountains, which are the product of one of the two major rift systems responsible for the formation of Oahu Island. The volcanoes are shield volcanoes that erupted primarily low-viscosity basaltic lava that cooled to form layers of varying thicknesses and characteristics depending on the eruptive, flow, and cooling conditions. These lava flows dip southwest down the flanks of the shield volcano, which lies to the northeast of the gulch.

Individual basalt flow thicknesses in the Waimanalo Gulch area range from approximately 4 feet to upwards of 20 feet and generally alternate between a relatively dense basalt lava flow and a less dense form of basalt called clinker. The exposed basalts are largely uniformly weathered within the depth of the gulch. The basalt flows are incised by infrequent but relatively large dikes composed of lighter, less dense diorite. The locations of the major dikes in the area have been mapped (Gartner Lee, Inc., 1992).

The project site geology cannot be interpreted at a detailed level based on the regional geologic information because of the layered form of the basalts. A seismic refraction survey conducted on the eastern side of the gulch by Geosyntec Consultants, Inc., on August 18, 2000 confirmed the subsurface layered structure and provided some shear wave velocity information in the basalts. The basalts are considered suitable for slope cuts as steep as 1H:1V in areas where water is present, and 0.5 H:1V where water is not present (Geolabs, Inc., 2003). The possible existence of lava tubes and very weak inclusions or weathered zones in the lava flow structures should be taken into consideration for design of the slope cuts. The potential presence of intrusive dikes within basalt layers is not expected to be detrimental to the performance of slope cuts.

In general, the project site is located in a regionally predictable but locally variable basalt formation that consists of both higher strength and lower strength layers and can include weathered rocks or local talus deposits. The geologic conditions will require direct observation and evaluation by an engineer as the specific conditions for slope stability and channel/pipe excavation are exposed during excavation.

4.0 Hydraulic Design

4.1 Hydraulic Model Analysis

The Western Surface Water Drainage Project conveyance consists of an open channel in the upper reach that has relatively flat grades and a partially full gravity pipeline for the remaining reaches with steep grades. An objective of the design was to achieve supercritical flow conditions in the pipe to avoid hydraulic instability, such as hydraulic jumps. Supercritical flow in the pipe also enables the pipe to be designed for partial-full pipe flow (open channel type flow). Designing for supercritical flow also enables use of smaller, more economical pipe sections. The constraints of the project site preclude the use of other conveyance system alignments or energy dissipaters, such as baffles, to reduce the overall grade and flow velocity.

The hydraulic design analysis was previously performed using the USACE HEC-RAS and Haestad Methods, Inc., Flow Master Version 4.1.c software to define the pipe diameter and channel cross-section dimensions and the hydraulic conditions for the drainage system. This earlier analysis was included in the Design Report issued June 2009.

Since June 2009 report several changes have occurred affecting the design basis previously utilized and a new set of revised drawings are prepared for the Western Surface Water Drainage Project.

The hydraulic analysis is re-done for the entire conveyance adopting the new design basis and prepared alignment drawings. A two dimensional Excel model is prepared and the direct step method is used for hydraulic analysis, as presented in Appendix A.

4.2 Diversion Structure

The diversion structure will consist of a 100-ft long reinforced concrete, side-channel weir structure having minimal submergence. The weir structure will control and impound a small head-water pond with a normal water surface elevation of 706.50 feet as controlled by the weir sill. Low flows from the gulch are discharged, at a slow rate, through the 12-inch diameter pipe outlet installed across the weir at side channel invert level.

The weir design capacity is 1,135-cfs at a weir sill elevation of 706.5 feet and with a side channel invert at El. 699. The 32-in. high parapet walls surrounding the diversion structure provide adequate free board to contain and direct the 100-year storm flow into the main drainage channel. An earlier side channel inlet configuration of the diversion structure on the right bank of the gulch was later changed due to construction space limitations. The new inlet is placed across the gulch. The inlet arrangement and sections are shown on Drawing C -08

The hydraulic analysis is carried on based on guidelines given in USBR publication “Design of Small Dams, third edition 1987, Chapter 9. The weir is sized for 25-year recurrence, 24-hours duration storm and additional freeboard is provided for 100-year recurrence storm.

4.3 Channel and Pipeline Conveyance

A revised plan and profile of the Western Surface Water Drainage conveyance alignment is prepared based on the planned footprint limit of the sanitary landfill expansion.

The rock channel segment of the Western Surface Water Drainage conveyance begins at the downstream end of the diversion structure at Station 64+83 (Drawing C -08) and extends southeast to Station 54+04 (Drawing C -09). The rock channel approximately 1,079 linear feet length of the conveyance is relatively flat with sub-critical flow velocities and is addressed by a channel having a grade that varies from 0.5 percent to 0.8 percent. The channel at the upstream end has rectangular concrete lined section for about 50-ft length. A coarse trashrack is installed within this concrete lined channel segment. The remaining length of the rock channel, 1,029 linear feet, is envisioned to have concrete lining only at the invert while the side slopes stabilized, as required, by fiber-shotcrete and fully grouted rock anchors. It is expected that the basalt rock formation along the alignment can allow 1H: 4V channel slope excavation for a significant length; stabilization with shotcrete and rock anchors will only be required at locally weaker rock zones.

A 40-ft long reinforced concrete rock trap is provided at the downstream end of the rock channel. A short reinforced concrete U-shaped channel, supporting a safety rack, connects the rock trap to the closed conduit system beginning at Station 53+46. (Drawing C- 09).

The transition from rectangular conduit cross section to HOBAS pipe section is done within Station 53+46 and Station 52+21 (Drawing C -09).

The pipe conveyance extends 5,190 linear feet downstream and drops 631 feet from El. 693 down to El. 61.4. The first 145 feet linear length of the pipe has 102-inch diameter HOBAS pipe and then the pipe diameter is reduced to 78-inch HOBAS pipe to continue for about 2,520 feet downstream dropping approximately 390 feet (Drawing C -06). Within this segment of the conveyance the pipe is buried in a trench as shown on Drawing C- 11.

Further downstream the pipe enters an existing Phase II concrete lined channel having a very flat 0.5% slope. The pipe diameter is increased to 84-inches to avoid full pipe sealing and unstable flow stage change. A typical cross section of the 84-inche diameter HOBAS pipe encased in the existing concrete lined channel is shown on Drawing C- 20.

The flow entering the 84-inch pipe has sufficient kinetic energy to continue downstream at partially full stage for about 600 linear feet before the pipe slope need to be increased to keep the partially full flow stage. At about Station 16+85 the HOBAS pipe leaves the existing

concrete lined channel alignment to continue with a gradually increasing slope as shown on (Drawing C -04. Downstream of the separation point at Station 16+85 to Station 1+03 the conveyance pipe is buried in a trench as shown on Drawing C -11. After leaving the concrete lined channel the conveyance pipe drops about 200-feet within approximately 1,685 linear feet.

4.4 Flip Bucket Structure and Plunge Pool

At Station 1+03 the pipe alignment makes a 56 degrees eastward turn to direct the flow towards a plunge pool with a flip bucket structure. Details of the flip bucket structure, plunge pool and pipe encasement at the 56 degree eastward bend are given on Drawings C -21 and C - 22.

The flip bucket structure is designed based on the guidelines given USBR publication “Hydraulic Design of Stilling Basins and Energy Dissipators”, 1963. The estimated length of jet trajectory for 25-year flood flow is approximately 60-feet. The plunge pool invert level is set at El. 54 in order to provide gravity flow downstream to the existing road culverts beneath the Farrington Highway. The bottom of the plunge pool will be lined with large size riprap to limit erosion. Low flow outlets from the plunge pool are provided by two 48-inch diameter pipes crossing the dike forming the southwest end of the plunge pool. The discharge capacity of the two 48-inch pipes will only be adequate to discharge low flows. At high flow the water depth in the pool will rise to flow over the dike crest at El. 60. The estimated flow depth over the dike crest is 1.8-feet for 25-year storm and 2.5 feet for a 100-year storm. Additional calculation details for the flip bucket and plunge pool will be presented in a subsequent report.

4.5 Channel Excavation

A plan for the future expansion of the sanitary landfill has been prepared by Geosyntec Consultants that shows general slope cuts required for landfill expansion, perimeter access road, and the Western Surface Water Drainage Project including the North Channel. General slope cuts to accommodate the project alignment and to form the 30 foot wide bench may be excavated as steep as $\frac{1}{2}(H):1(V)$ based on the GeoSyntec topographic information. However, in practice these large slope cuts may be excavated at a flatter slope to accommodate site development methods and where the property boundary allows sufficient room. Where the property line is close and does not allow sufficient width for the channel/pipeline construction bench, then the slope cut will need to be steepened or a retaining structure will need to be designed based on the interpreted geology at these specific sites. Once the bench is cut, an engineering and geologic evaluation along the channel alignment will be required to determine excavation approach and any localized need for special slope stabilization or channel construction measures. General slope stability has not been evaluated or addressed in this design information for the Western Surface Water Drainage Project permit application.

The western limit of the future landfill expansion is close to the City and County of Honolulu's property line at certain locations. At these locations, a maximum 30 foot bench width is available for construction of the Western Drainage project channel and access road, and pipe. Where an access road is needed along the buried pipe portion of the alignment, the access road can be constructed on top of the pipe assuming appropriate traffic loads and the minimum 3 feet of pipe cover are maintained.

Channel excavation will be performed in two phases. First, general slope cuts will be made according to the grading plan for the landfill expansion. These general cuts will include forming a 30-ft wide bench for the Western Surface Water Drainage Project at the required grade. The bench will approximately follow the landfill limit elevation. Second, excavation of the Western Surface Water Drainage Project channel section or pipe trench will be made. The channel excavation should be performed carefully by pre-split blasting along the channel slope lines to obtain neat surfaces in the rock, followed by excavation of the channel in benches between the blasted lines.

Appendix A

Hydraulic Calculations

Side Channel and Inlet Structure

Channel and Pipe Conveyance, 25-year recurrence, 24-hour duration

Channel and Pipe Conveyance, 100-year recurrence, 24-hour duration

Flip Bucket

Client	Waste Management	Project	070180	Page	1/
Subject	Side Channel Inlet	Date	March 2009	By	AT
		Checked	6-5-09	By	CA
		Approved		By	

COVER SHEET

FEATURE: Western Surface Water Drainage Project, Side Channel Inlet.
Hydraulic Calculations

REFERENCE: U. S. Bureau of Reclamation, "Design of Small Dams"
Third Edition, 1987

WAIMANALO GULCH LANDFILL		Project 07018	Page
Client		Date 05.25.09	By [Signature]
Subject	DIVERSION STRUCTURE	Checked 6-5-09	By CA
		Approved	By

DIVERSION STRUCTURE

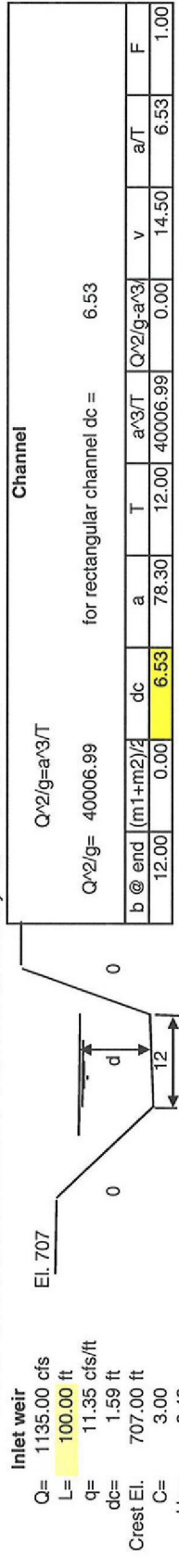
The diversion structure construction site, within steep rocky slopes of the Waimanalo Gulch, is bounded by the property line at the north side, and by the future landfill at south side. A side channel inlet configuration was the only fitting option in the limited space. Different weir lengths were analyzed to determine the optimum size. Shorter weirs required higher structures than the future bench elevation. After several trials 100-ft long weir is selected. For the 1135-cfs design flow computed maximum water level in the channel is El. 708.02, about four foot lower than the top of channel walls.

The walls surrounding the diversion structure are raise 32-inches with a continuous parapet wall to avoid any spill out in an unusual storm event.

The adopted side channel inlet will create a small headwater pond during flood flows. The pond will stop most of the sediments and debris carried by the flood flows. Cleaning of the sediments deposited in the pond area should be carried as a routine maintenance work to avoid damages to the downstream segments of the conveyance.

CA
6-5-09
✓

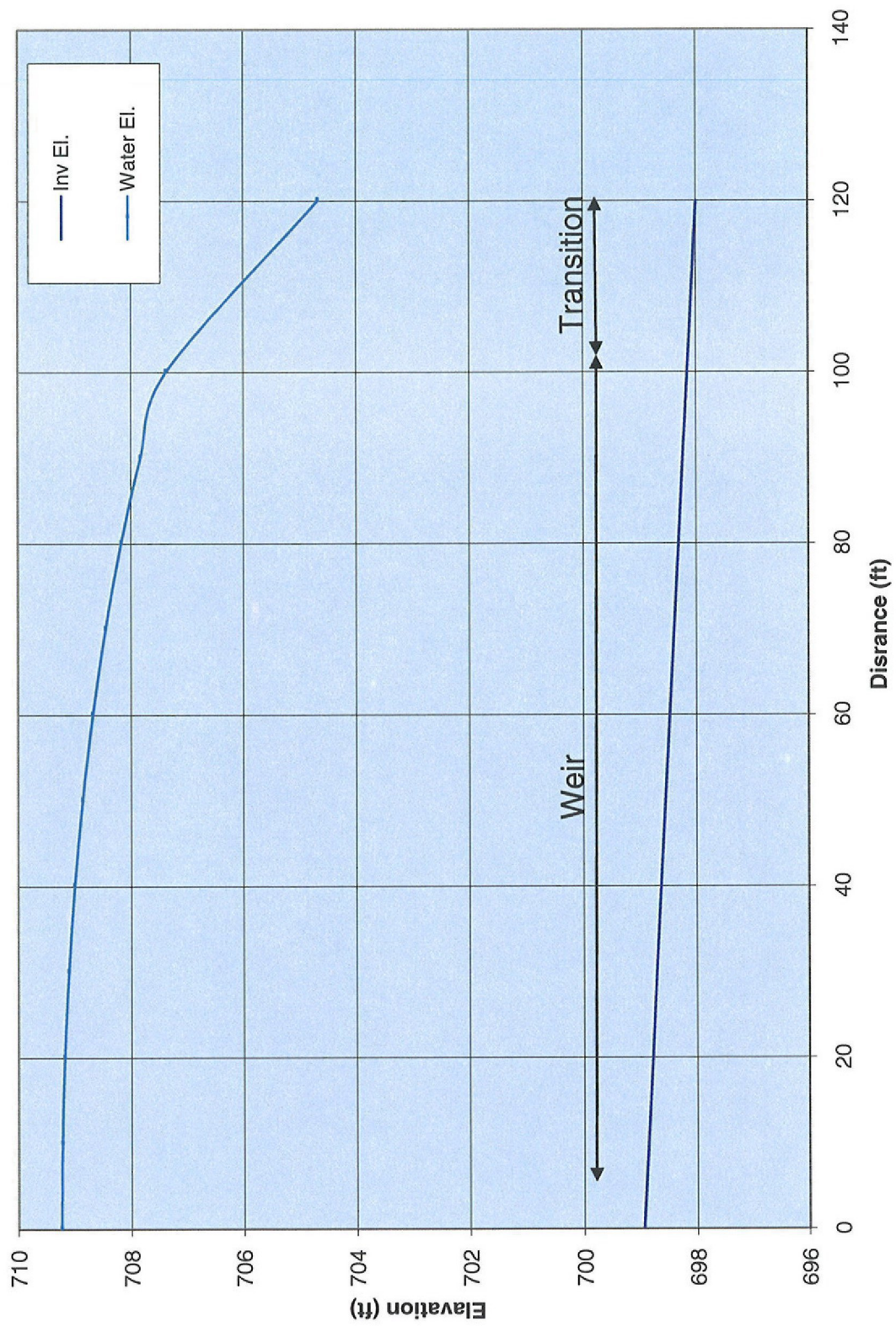
SIDE CHANNEL INLET HUDRAULICS, Q = 1135-cfs



Station	Δx	Invert El.	Δy	Water El.	d	a	Q	v	EGL	Q1+Q2	Q1/(Q1+Q2)g	v1+v2	v2-v1	Q2-Q1	(Q2-Q2)/Q1	v2/(Q2-Q1)Q1	(13)+(16)	(17)	(18)	(19)
120		698.000	0.45	704.685	6.53	78.30	1135.00	14.50	708.397											
transition																				
100	20.00	698.160		707.38	9.22	140.46	1135.00	8.08	708.40											
90	10.00	698.240	0.45	707.84	9.60	147.37	1021.50	6.93	708.58	2156.50	0.01	15.01	1.15	113.50	0.11	0.90	2.05	0.452104	0.00	0.00
80	10.00	698.320	0.35	708.18	9.86	152.39	908.00	5.96	708.73	1929.50	0.01	12.89	0.97	113.50	0.13	0.87	1.84	0.346478	0.00	0.00
70	10.00	698.400	0.28	708.46	10.06	156.09	794.50	5.09	708.86	1702.50	0.01	11.05	0.87	113.50	0.14	0.85	1.72	0.275382	0.00	0.00
60	10.00	698.480	0.22	708.68	10.20	158.80	681.00	4.29	708.96	1475.50	0.01	9.38	0.80	113.50	0.17	0.85	1.65	0.221769	0.00	0.00
50	10.00	698.560	0.18	708.86	10.30	160.68	567.50	3.53	709.05	1248.50	0.01	7.82	0.76	113.50	0.20	0.86	1.61	0.178203	0.00	0.00
40	10.00	698.640	0.14	709.00	10.36	161.85	454.00	2.81	709.12	1021.50	0.01	6.34	0.73	113.50	0.25	0.88	1.61	0.140791	0.00	0.00
30	10.00	698.720	0.11	709.11	10.39	162.38	340.50	2.10	709.17	794.50	0.01	4.90	0.71	113.50	0.33	0.94	1.64	0.107198	0.00	0.00
20	10.00	698.800	0.08	709.18	10.38	162.30	227.00	1.40	709.21	567.50	0.01	3.50	0.70	113.50	0.50	1.05	1.75	0.075853	0.00	0.00
10	10.00	698.880	0.05	709.23	10.35	161.63	113.50	0.70	709.23	340.50	0.01	2.10	0.70	113.50	1.00	1.40	2.10	0.045565	0.00	0.00
0	10.00	698.960	0.01	709.24	10.28	160.33	50.00	0.31	709.24	163.50	0.01	1.01	0.39	63.50	1.27	0.89	1.28	0.012348	0.00	0.00

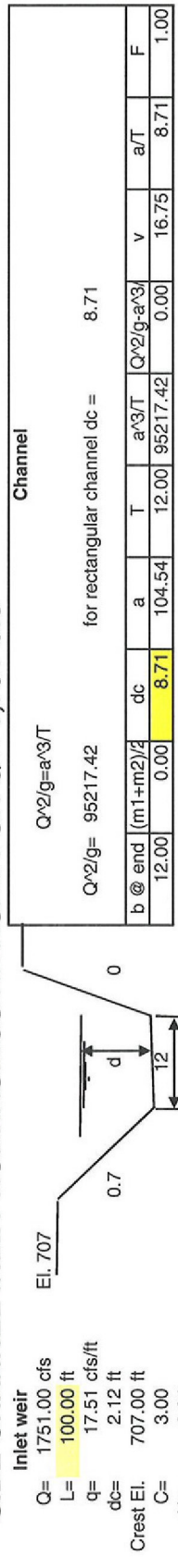
CA
6-5-09
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Waimanalo Gulch Side Channel Inlet Water Levels (ft), Q = 1135-cfs



CA
6-5-09
✓

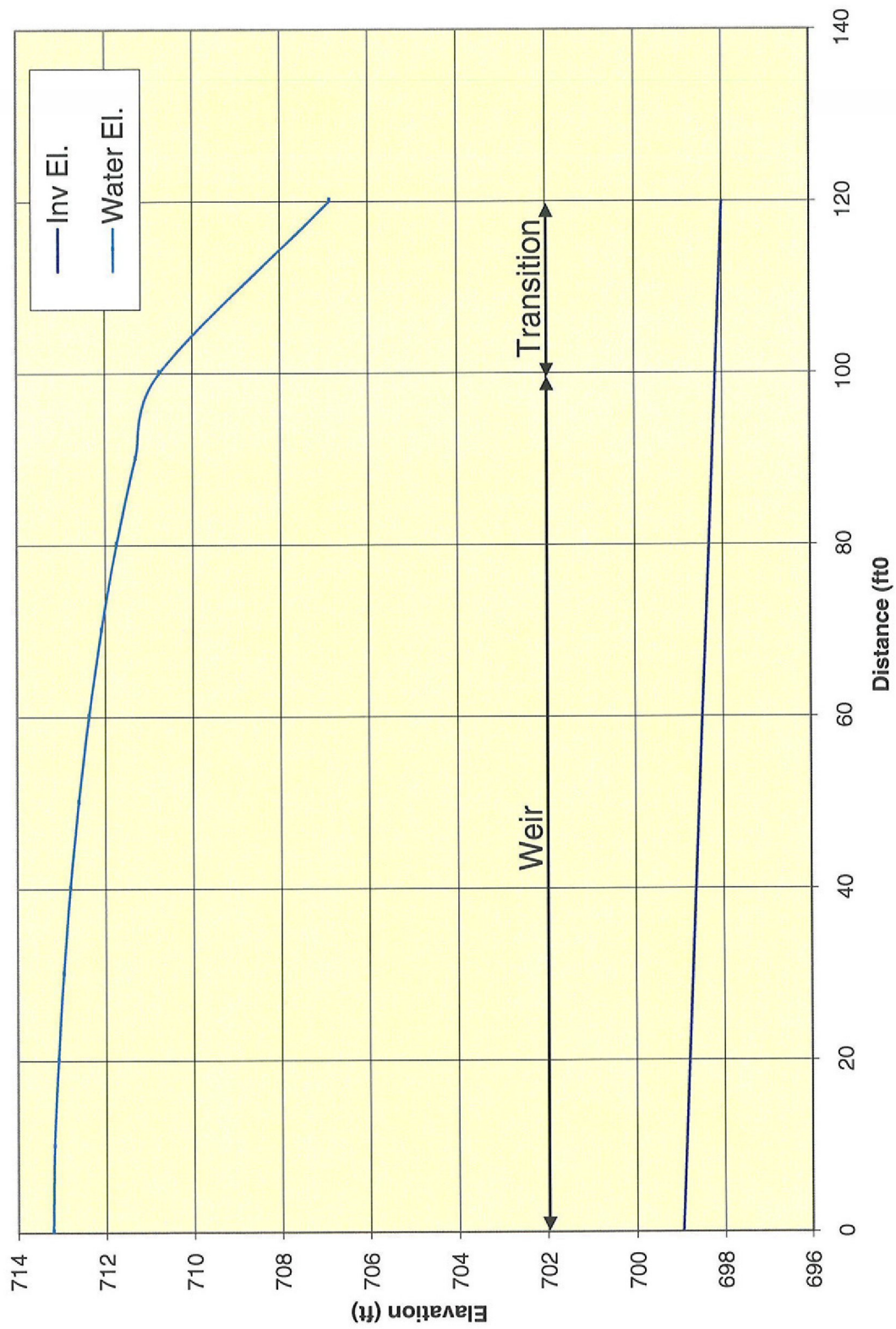
SIDE CHANNEL INLET HUDRAULICS REVISED FOR Q = 1,751-cfs



Station	Δx	Invert El.	Δy	Water El.	d	a	Q	v	EGL	Q1+Q2	Q1/(Q1+Q2)g	v1+v2	v2-v1	Q2-Q1	(Q2-Q2)/Q1	v2(Q2-Q1)/Q1	Δy=(11)-(12)+(17)	Remark
120		698.000	0.65	706.872	8.71	104.54	1751.00	16.75	711.877									
transition																		
100	20.00	698.160		710.76	12.60	206.85	1751.00	8.47	711.88									
90	10.00	698.240	0.55	711.31	13.07	216.69	1575.90	7.27	712.13	3326.90	0.02	15.74	1.19	175.10	0.11	0.94	2.13	0.55
80	10.00	698.320	0.43	711.74	13.42	224.12	1400.80	6.25	712.35	2976.70	0.02	13.52	1.02	175.10	0.13	0.91	1.93	0.43
70	10.00	698.400	0.35	712.09	13.69	229.87	1225.70	5.33	712.53	2626.50	0.02	11.58	0.92	175.10	0.14	0.89	1.81	0.35
60	10.00	698.480	0.29	712.37	13.89	234.31	1050.60	4.48	712.69	2276.30	0.02	9.82	0.85	175.10	0.17	0.89	1.74	0.29
50	10.00	698.560	0.23	712.61	14.05	237.68	875.50	3.68	712.82	1926.10	0.02	8.17	0.80	175.10	0.20	0.90	1.70	0.23
40	10.00	698.640	0.19	712.80	14.16	240.14	700.40	2.92	712.93	1575.90	0.02	6.60	0.77	175.10	0.25	0.92	1.69	0.19
30	10.00	698.720	0.16	712.96	14.24	241.78	525.30	2.17	713.03	1225.70	0.02	5.09	0.74	175.10	0.33	0.97	1.72	0.16
20	10.00	698.800	0.12	713.08	14.28	242.71	350.20	1.44	713.11	875.50	0.02	3.62	0.73	175.10	0.50	1.09	1.82	0.12
10	10.00	698.880	0.10	713.18	14.30	243.09	175.10	0.72	713.18	525.30	0.02	2.16	0.72	175.10	1.00	1.44	2.17	0.10
0	10.00	698.960	0.03	713.21	14.25	242.00	75.00	0.31	713.21	250.10	0.02	1.03	0.41	100.10	1.33	0.96	1.37	0.03
Max Water Level																		
EI 712 +32'/12 =																		
713																		
715																		

CA
6-5-09
✓

Waimanalo Gulch Side Channel Inlet
Water levels (ft), Q = 1751-cfs



Client **WAIMANALO GULCH LANDFILL**
 Subject **INLET STRUCTURES**

Project **07012** Page **1**
 Date **03/26/07** By **J. J. J.**
 Checked By
 Approved By

DESIGN THE SYSTEM FOR 25-FLOOD
 ALLOW FB TO PASS 100-YR FLOOD

Per GeoSyntec e-mail dated 6/7/07
 peak flows are as follows:

Peak Flows by Junction

	Area (acres)	Q2	Q5	Q10	Q25	Q50	Q100
J-3	540	196	496	766	1135	1450	1751
J-4	548	195	498	766	1133	1452	1755
J-5	562	198	502	776	1141	1464	1773
J-6	562	198	502	776	1141	1464	1773

DAM CREST EL. 712
 use 2' FB for normal operation & estimate weir
 height & length.

INLET WEIR

Design Q	Weir length		dc40	dc50	Dam Crest	FB	Selected	
							Weir Crest	
1135	40	50			El.		L=40	L=50
q	28.38	22.70	2.92	2.52	712	2.00	707.08	707.48
100-year								
1751	43.78	35.02	3.90	3.36	712.00	1.00	707.10	707.64

weir EL. 707, FB=2.00 ✓

Client	<u>Waste Management</u>	Project	<u>070181</u>	Page	<u>1/4</u>
Subject	<u>Waimanalo Gulch</u>	Date	<u>Nov. 13, 2009</u>	By	<u>AT</u>
		Checked	<u>Nov. 24, 2009</u>	By	<u>C. J. S.</u>
		Approved		By	

Western Surface Water Drainage Project

Hydraulic calculations For 25-year, 24-hour Storm

October 29, 2009

WESTERN WATER SURFACE DRAINAGE
HYDRAULICS, STARTING FROM DRAWING C-506 DOWNSTREAM PROFILE
WATER SURFACE PROFILE

Trapezoidal Channel
m = 0.25

Q = 1135

n = 0.011 for HOBAS

n = 0.014 for conc.

Station	Invert	So	Dia	Y	Δ	B	A	P	R	T	Q	V	Sf	Stavg	EGL	GL-Hv-A/B	Y/D	Froude
6487	699	0.50%		6.24		12.00	74.85	24.48	3.06	12.00	1135.00	15.16	0.00460		715.05	0.00		1.07
6423	698.6792	0.50%		6.27		12.00	75.24	24.54	3.07	12.00	1135.00	15.09	0.00453	0.004566	714.75	0.00		1.06
6323	698.1792	0.50%		6.33		12.00	75.94	24.66	3.08	12.00	1135.00	14.95	0.00442	0.00448	714.30	0.00		1.05
6223	697.6792	0.50%		6.40		12.00	76.77	24.80	3.10	12.00	1135.00	14.78	0.00430	0.004362	713.87	0.00		1.03
6123	697.1792	0.50%		6.48		12.00	77.74	24.96	3.11	12.00	1135.00	14.60	0.00416	0.004229	713.45	0.00		1.01
6023	696.6792	0.50%		6.57		12.00	78.84	25.14	3.14	12.00	1135.00	14.40	0.00401	0.004083	713.04	0.00		0.99
5923	696.1792	0.50%		6.67		12.00	80.08	25.35	3.16	12.00	1135.00	14.17	0.00385	0.003927	712.64	0.00		0.97
5823	695.6792	0.50%		6.79		12.00	81.44	25.57	3.18	12.00	1135.00	13.94	0.00368	0.003763	712.27	0.00		0.94
5723	695.1792	0.50%		6.91		12.00	82.92	25.82	3.21	12.00	1135.00	13.69	0.00351	0.003595	711.91	0.00		0.92
5623	694.6792	0.50%		7.04		12.00	84.53	26.09	3.24	12.00	1135.00	13.43	0.00334	0.003424	711.57	0.00		0.89
5523	694.1792	0.50%		7.19		12.00	86.23	26.37	3.27	12.00	1135.00	13.16	0.00317	0.003253	711.24	0.00		0.87
5423	693.6792	0.50%		7.34		12.00	88.04	26.67	3.30	12.00	1135.00	12.89	0.00300	0.003085	710.93	0.00		0.84
5403.70	693.5827	0.50%		7.37		12.00	88.39	26.73	3.31	12.00	1135.00	12.84	0.00297	0.002986	710.88	0.00		0.83
5360.7	693.1527	1.00%		7.60		12.00	91.15	27.19	3.35	12.00	1135.00	12.45	0.00274	0.002857	710.75	0.00		0.80
10x12 box		2.50%		7.83		12.00	93.99	27.66	3.40	12.00	1135.00	12.08	0.00253	0.002639	710.71	0.00		0.76
5346.0	692.7852	7.00%		2.83		12.00	34.00	17.67	1.92	12.00	1135.00	33.38	0.04133	0.021931	709.70	0.00		3.50
5300	689.5652	7.00%		2.80		12.00	33.56	17.59	1.91	12.00	1135.00	33.82	0.04292	0.042122	709.07	0.00		3.56
5285	688.5152	7.00%		2.77		12.00	33.19	17.53	1.89	12.00	1135.00	34.20	0.04433	0.043623	708.46	0.00		3.62
5271.0	687.5352	10.00%		3.16		10.00	31.55	16.31	1.93	10.00	1135.00	35.97	0.04765	0.0460	706.48	0.00		3.57
10x10 box		19.25%												0.0437				
5228.0	683.2352																	
10x10 to 8.5 round																		

5221 682.174	8.50	4.61	1.65	8.47	31.39	14.06	2.23	8.47	1135.00	36.16	0.03977		706.18	0.00	0.54	3.31
102" HIOBAS	19.25%											0.0422				
5176 669.6	8.50	3.87	1.48	8.47	25.11	12.58	2.00	8.47	1135.00	45.19	0.04454		704.28	0.00	0.45	4.62
102" TO 84"	20.96%											0.0451				
5170 668.3424	7.00	4.33	1.81	6.80	25.01	12.67	1.97	6.80	1135.00	45.39	0.04562		704.01	0.00	0.62	4.17
	20.96%											0.0773				
4951 622.44	7.00	3.32	1.52	6.99	17.95	10.63	1.69	6.99	1135.00	63.23	0.10890		687.09	0.00	0.47	6.95
	20.96%											2.9291				
5320 699.7824	7.00	1.19	0.85	5.26	4.33	5.95	0.73	5.26	1135.00	262.17	5.74927		1767.92	0.00	0.17	50.91
	20.96%											4.5490				
5245 684.0624	6.50	1.39	0.96	5.33	5.19	6.25	0.83	5.33	1135.00	218.56	3.34865		1426.75	0.00	0.21	39.02
	20.96%											1.9801				
4951 622.44	6.50	2.14	1.22	6.11	9.52	7.95	1.20	6.11	1135.00	119.19	0.61154		844.60	0.00	0.33	16.82
	20.96%											0.5472				
4849 601.06	6.50	2.28	1.27	6.20	10.37	8.24	1.26	6.20	1135.00	109.46	0.48295		788.78	0.00	0.35	14.92
	20.96%											0.4245				
4692 568.15	6.50	2.45	1.32	6.30	11.47	8.60	1.33	6.30	1135.00	98.99	0.36599		722.14	0.00	0.38	12.93
	20.96%											0.3660				
4692 568.15	6.50	2.45	1.32	6.30	11.47	8.60	1.33	6.30	1135.00	98.99	0.36599		722.14	0.00	0.38	12.93
	20.96%											0.3011				
4185.70 457.11	6.50	2.77	1.42	6.43	13.45	9.24	1.46	6.43	1135.00	84.36	0.23618		569.70	0.00	0.43	10.27
vertical curve												0.2215				
4050 437.21	6.50	2.87	1.45	6.46	14.13	9.45	1.50	6.46	1135.00	80.35	0.20690		539.64	0.00	0.44	9.57
vertical curve												0.1994				
3905.70 413.77	6.50	2.93	1.47	6.47	14.52	9.57	1.52	6.47	1135.00	78.16	0.19198		510.86	0.00	0.45	9.19
	10.00%											0.1697				
3665.70 389.77	6.50	3.16	1.54	6.50	16.02	10.04	1.60	6.50	1135.00	70.83	0.14732		470.14	0.00	0.49	7.95
vertical curve												0.1387				
3525.70 377.14	6.50	3.28	1.58	6.50	16.78	10.27	1.63	6.50	1135.00	67.62	0.13014		450.72	0.00	0.50	7.42
	15.18%											0.1343				
3336.00 348.34	6.50	3.22	1.56	6.50	16.40	10.15	1.62	6.50	1135.00	69.21	0.13847		425.24	0.00	0.50	7.68
	22.82%											0.1454				
3270.70 333.44	6.50	3.13	1.53	6.50	15.83	9.97	1.59	6.50	1135.00	71.72	0.15232		415.75	0.00	0.48	8.10
vertical curve												0.1449				
3070.70 310.26	6.50	3.23	1.56	6.50	16.44	10.16	1.62	6.50	1135.00	69.03	0.13748		386.77	0.00	0.50	7.65
	11.59%											0.1232				
	8.00%											0.1018				
2800.70 288.66	6.50	3.46	1.64	6.49	17.95	10.63	1.69	6.49	1135.00	63.23	0.10893		353.50	0.00	0.53	6.70
Vertical curve												0.0925				
2740.70 288.66	6.50	3.61	1.68	6.46	18.93	10.93	1.73	6.46	1135.00	59.95	0.09471		347.40	0.00	0.56	6.17
	6.95%											0.0884				
2655 282.7039	6.50	3.67	1.70	6.45	19.29	11.04	1.75	6.45	1135.00	58.85	0.09024		339.47	0.00	0.56	6.00
End by-pass beg. New	6.95% INCREASE PIPESIZE											0.0849				
2593 278.91	7.00	3.55	1.58	7.00	19.56	11.09	1.76	7.00	1135.00	58.03	0.08655		333.99	0.00	0.51	6.12
	6.95%											0.0811				
2496 272.1685	7.00	3.59	1.60	7.00	19.85	11.17	1.78	7.00	1135.00	57.17	0.08319		325.76	0.00	0.51	5.98
												0.0591				
2405.70 266.69	7.00	3.64	1.61	6.99	20.24	11.28	1.79	6.99	1135.00	56.09	0.07908		318.43	0.00	0.52	5.81
	0.50%															
2045.70 264.89	7.00	4.57	1.88	6.67	26.59	13.16	2.02	6.67	1135.00	42.68	0.03908		297.16	0.00	0.65	3.77

1945.70	264.09	0.80%	7.00	4.82	1.96	6.49	28.24	13.70	2.06	6.49	1135.00	40.19	0.03372	0.0364	293.52	0.00	0.69	3.39
1845.70	262.09	2.00%	7.00	4.95	2.00	6.37	29.11	13.99	2.08	6.37	1135.00	38.99	0.03137	0.0325	290.27	0.00	0.71	3.21
1745.70	259.09	3.00%	7.00	4.97	2.00	6.36	29.20	14.02	2.08	6.36	1135.00	38.87	0.03113	0.0312	287.14	0.00	0.71	3.20
1645.70	247.09	12.00%	7.00	4.30	1.80	6.81	24.80	12.61	1.97	6.81	1135.00	45.77	0.04660	0.0389	283.25	0.00	0.61	4.23
1495.70	237.69		7.00	4.18	1.77	6.87	23.99	12.37	1.94	6.87	1135.00	47.32	0.05074	0.0487	275.95	0.00	0.60	4.46
1395.70	223.39		7.00	3.81	1.66	6.97	21.43	11.62	1.84	6.97	1135.00	52.96	0.06797	0.1019	270.02	0.00	0.54	5.32
898	143.758	16.00%	7.00	3.11	1.46	6.96	16.54	10.22	1.62	6.96	1135.00	68.64	0.13589	0.1386	219.29	0.00	0.44	7.85
800	128.078	16.00%	7.00	3.08	1.45	6.95	16.30	10.15	1.61	6.95	1135.00	69.63	0.14128	0.1441	205.71	0.00	0.44	8.01
665.70	106.59	12.00%	7.00	3.05	1.44	6.94	16.07	10.08	1.59	6.94	1135.00	70.63	0.14684	0.1387	186.36	0.00	0.44	8.18
vertical curve																		
425.70	79.59		7.00	3.15	1.47	6.96	16.78	10.29	1.63	6.96	1135.00	67.65	0.13065	0.1280	153.06	0.00	0.45	7.68
365.70	74.04		7.00	3.18	1.48	6.97	17.04	10.36	1.64	6.97	1135.00	66.61	0.12531	0.1211	145.38	0.00	0.45	7.51
335.70	73.79		7.00	3.25	1.50	6.98	17.48	10.49	1.67	6.98	1135.00	64.93	0.11693	0.1098	141.75	0.00	0.46	7.23
200	64.802	6.62%	7.00	3.37	1.53	7.00	18.35	10.74	1.71	7.00	1135.00	61.86	0.10268	0.1003	126.85	0.00	0.48	6.73
150	61.802	6.00%	7.00	3.42	1.55	7.00	18.67	10.83	1.72	7.00	1135.00	60.78	0.09794	0.0919	121.83	0.00	0.49	6.56
90	61.502	0.50%	7.00	3.55	1.59	7.00	19.61	11.10	1.77	7.00	1135.00	57.88	0.08595	0.0810	116.32	0.00	0.51	6.09
34	61.39	0.20%	7.00	3.68	1.62	6.99	20.53	11.36	1.81	6.99	1135.00	55.28	0.07610		111.78	0.00	0.53	5.68

Client	Waste Management	Project	070181	Page	1/4
Subject	Waimanalo Gulch	Date	Nov. 13, 2009	By	AT
		Checked	Nov 24, 2009	By	JDS
		Approved		By	

Western Surface Water Drainage Project

Hydraulic Calculations For 100-year, 24-hour Storm

October 29, 2009
 WESTERN WATER SURFACE DRAINAGE
 HYDRAULICS, STARTING FROM DRAWING C- 506 DOWNSTREAM PROFILE
 WATER SURFACE PROFILE

Trapezoidal Channel
 m = 0.25

Q = 1751

n = 0.011 for HOBAS
 n = 0.014 for conc.

Station	Invert	So	Dia	Y	Δ	B	A	P	R	T	Q	V	Sf	Sfavg	EGL	GL-Hv-A/B	Y/D	Froude
6637	699	0.50%		12.00		12.00	144.00	36.00	4.00	12.00	1751.00	12.16	0.00207		725.30	0.00		0.62
6600	698.815	0.50%		12.07		12.00	144.81	36.13	4.01	12.00	1751.00	12.09	0.00204	0.002053	725.22	0.00		0.61
6500	698.315	0.50%		12.25		12.00	147.01	36.50	4.03	12.00	1751.00	11.91	0.00197	0.002002	725.02	0.00		0.60
6400	697.815	0.50%		12.44		12.00	149.25	36.87	4.05	12.00	1751.00	11.73	0.00189	0.00193	724.83	0.00		0.59
6300	697.315	0.50%		12.63		12.00	151.51	37.25	4.07	12.00	1751.00	11.56	0.00183	0.00186	724.64	0.00		0.57
6200	696.815	0.50%		12.82		12.00	153.80	37.63	4.09	12.00	1751.00	11.38	0.00176	0.001793	724.46	0.00		0.56
6100	696.315	0.50%		13.01		12.00	156.12	38.02	4.11	12.00	1751.00	11.22	0.00170	0.001729	724.29	0.00		0.55
6000	695.815	0.50%		13.21		12.00	158.46	38.41	4.13	12.00	1751.00	11.05	0.00164	0.001668	724.12	0.00		0.54
5900	695.315	0.50%		13.40		12.00	160.83	38.81	4.14	12.00	1751.00	10.89	0.00158	0.001609	723.96	0.00		0.52
5800	694.815	0.50%		13.60		12.00	163.22	39.20	4.16	12.00	1751.00	10.73	0.00153	0.001553	723.81	0.00		0.51
5700	694.315	0.50%		13.80		12.00	165.63	39.61	4.18	12.00	1751.00	10.57	0.00147	0.001499	723.66	0.00		0.50
5600	693.815	0.50%		14.00		12.00	168.06	40.01	4.20	12.00	1751.00	10.42	0.00142	0.001447	723.51	0.00		0.49
5558	693.605	0.50%		14.09		12.00	169.09	40.18	4.21	12.00	1751.00	10.36	0.00140	0.001411	723.45	0.00		0.49
5515	693.175	1.00%		14.30		12.00	171.60	40.60	4.23	12.00	1751.00	10.20	0.00135	0.001377	723.39	0.00		0.48
10x12 box 5500	692.8	2.50%		14.50		12.00	174.00	41.00	4.24	12.00	1751.00	10.06	0.00131	0.00133	723.37	0.00		0.47
5492	692.224	7.20%		3.47		12.00	41.64	18.94	2.20	12.00	1751.00	42.05	0.05489	0.028099	723.15	0.00		3.98
5470	690.64	7.20%		3.45		12.00	41.35	18.89	2.19	12.00	1751.00	42.34	0.05600	0.055445	721.93	0.00		4.02
5425	687.4	7.20%		3.40		12.00	40.83	18.80	2.17	12.00	1751.00	42.89	0.05807	0.057032	719.36	0.00		4.10
10x10 box 5410	685.9	10.00%		4.09		10.00	40.85	18.17	2.25	10.00	1751.00	42.86	0.05536	0.0567	718.51	0.00		3.74
		19.27%												0.0592				

Station	Invert	So	Dia	Y	A	B	P	R	T	Q	V	Sf	Sfavg	EGL	GL-Hv-A/B	Y/D	Froude
5390	682.0452	20.96%	8.50	3.89	38.95	10.00	17.79	2.19	10.00	1751.00	44.96	0.06311	0.0604	717.33	0.00		4.01
10x10 to 8.5 round																	
5375	678.9012	20.96%	8.50	5.40	38.06	8.18	15.69	2.43	8.18	1751.00	46.01	0.05764	0.0576	716.42	0.00	0.64	3.76
102" HOBAS																	
5375	678.9012	20.96%	8.50	5.40	38.06	8.18	15.69	2.43	8.18	1751.00	46.01	0.05764	0.0657	716.42	0.00	0.64	3.76
102" TO 78"																	
5330	669.4692	20.96%	8.00	5.22	34.75	7.62	15.05	2.31	7.62	1751.00	50.39	0.07385	0.0756	713.46	0.00	0.65	4.16
78" HOBAS																	
5320	667.3732	20.96%	8.00	5.14	34.12	7.67	14.88	2.29	7.67	1751.00	51.31	0.07726	0.0904	712.71	0.00	0.64	4.29
72" HOBAS																	
5245	651.6532	20.96%	7.00	5.28	31.14	6.03	14.73	2.11	6.03	1751.00	56.24	0.10347	0.1302	705.93	0.00	0.75	4.36
72" to "																	
5003	600.93	20.96%	7.00	4.50	26.16	6.71	13.03	2.01	6.71	1751.00	66.94	0.15702	0.1670	674.41	0.00	0.64	5.97
4846	568.02	20.96%	7.00	4.32	24.95	6.80	12.66	1.97	6.80	1751.00	70.19	0.17695	0.1913	648.19	0.00	0.62	6.46
4340	461.97	20.96%	7.00	4.11	23.52	6.89	12.23	1.92	6.89	1751.00	74.43	0.20561	0.2017	551.41	0.00	0.59	7.10
4204	437.02	20.96%	7.00	4.17	23.88	6.87	12.34	1.94	6.87	1751.00	73.32	0.19781	0.1852	523.97	0.00	0.60	6.93
vertical curve																	
4060	418.60	10.00%	7.00	4.36	25.20	6.79	12.73	1.98	6.79	1751.00	69.50	0.17254	0.1649	497.31	0.00	0.62	6.36
3950	405.60	8.46%	7.00	4.50	26.14	6.71	13.02	2.01	6.71	1751.00	66.98	0.15728	0.1458	479.17	0.00	0.64	5.98
3820	394.60	12.59%	7.00	4.76	27.86	6.53	13.57	2.05	6.53	1751.00	62.85	0.13440	0.1330	460.21	0.00	0.68	5.36
vertical curve																	
3680	376.98	15.18%	7.00	4.80	28.10	6.50	13.65	2.06	6.50	1751.00	62.31	0.13160	0.1369	441.59	0.00	0.69	5.28
3425	338.28	11.59%	7.00	4.66	27.22	6.60	13.36	2.04	6.60	1751.00	64.33	0.14229	0.1365	406.67	0.00	0.67	5.58
vertical curve																	
3225	315.10	8.00%	7.00	4.81	28.18	6.49	13.68	2.06	6.49	1751.00	62.13	0.13066	0.1171	379.38	0.00	0.69	5.25
2955	293.5	7.47%	7.00	5.28	31.14	6.03	14.73	2.11	6.03	1751.00	56.24	0.10345	0.1013	347.77	0.00	0.75	4.36
vertical curve																	
2895	289.02	6.95%	7.00	5.38	31.73	5.91	14.96	2.12	5.91	1751.00	55.19	0.09923	0.0990	341.69	0.00	0.77	4.20
2888	288.5335	6.95%	7.00	5.39	31.80	5.89	14.99	2.12	5.89	1751.00	55.05	0.09869	0.0954	341.00	0.00	0.77	4.18
2790	281.7225	6.95%	7.00	5.57	32.86	5.64	15.43	2.13	5.64	1751.00	53.29	0.09206	0.0737	331.65	0.00	0.80	3.89
2750	278.93	0.50% INCREASE PIPESIZE	7.50	5.17	32.49	6.94	14.70	2.21	6.94	1751.00	53.89	0.05525	0.0593	328.71	0.00	0.69	4.39
End by-pass beg. New																	
2700	271	0.50%	7.50	4.92	30.73	7.13	14.16	2.17	7.13	1751.00	56.99	0.06336	0.0590	325.74	0.00	0.66	4.84
2600	270.5	0.50%	7.50	5.20	32.66	6.92	14.75	2.21	6.92	1751.00	53.61	0.05456	0.0527	319.84	0.00	0.69	4.35
2550	270.25	0.50%	7.50	5.34	33.67	6.79	15.07	2.23	6.79	1751.00	52.01	0.05076	0.0490	317.21	0.00	0.71	4.12

Station	Invert	So	Dia	Y	Δ	B	A	P	R	T	Q	V	Sf	Sfavg	EGL	GL-HV-A/B	Y/D	Froude
2500	270		7.50	5.50	2.06	6.64	34.70	15.42	2.25	6.64	1751.00	50.46	0.04728		314.76	0.00	0.73	3.89
2450	269.75	0.50%	7.50	5.66	2.11	6.45	35.78	15.79	2.27	6.45	1751.00	48.93	0.04409	0.0457	312.48	0.00	0.76	3.66
2400	269.5	0.50%	7.50	5.84	2.16	6.22	36.93	16.22	2.28	6.22	1751.00	47.42	0.04114	0.0426	310.34	0.00	0.78	3.43
2300	268.5	1.00%	7.50	6.22	2.29	5.64	39.18	17.18	2.28	5.64	1751.00	44.70	0.03646	0.0388	306.46	0.00	0.83	2.99
2200	265.5	3.00%	7.50	6.33	2.33	5.43	39.81	17.48	2.28	5.43	1751.00	43.99	0.03540	0.0359	302.87	0.00	0.84	2.86
2100	262.5	3.00%	7.50	6.46	2.38	5.19	40.46	17.83	2.27	5.19	1751.00	43.28	0.03442	0.0349	299.38	0.00	0.86	2.73
2000	259.5	3.00%	7.50	6.63	2.44	4.81	41.30	18.34	2.25	4.81	1751.00	42.40	0.03336	0.0339	295.99	0.00	0.88	2.55
1900	256	3.50%	7.50	6.55	2.41	5.00	40.91	18.09	2.26	5.00	1751.00	42.80	0.03382	0.0336	292.63	0.00	0.87	2.64
1800	251	5.00%	7.50	6.20	2.28	5.68	39.04	17.11	2.28	5.68	1751.00	44.85	0.03670	0.0353	289.11	0.00	0.83	3.02
1700	239	12.00%	7.50	5.42	2.03	6.72	34.19	15.24	2.24	6.72	1751.00	51.22	0.04896	0.0428	284.82	0.00	0.72	4.00
1600	226	13.00%	7.50	4.99	1.91	7.08	31.20	14.30	2.18	7.08	1751.00	56.13	0.06102	0.0550	279.32	0.00	0.66	4.71
1500	210	16.00%	7.50	4.61	1.80	7.30	28.52	13.53	2.11	7.30	1751.00	61.40	0.07642	0.0687	272.45	0.00	0.62	5.47
1400	194	16.00%	7.50	4.37	1.74	7.40	26.75	13.04	2.05	7.40	1751.00	65.45	0.09000	0.0832	264.13	0.00	0.58	6.06
1300	178	16.00%	7.50	4.21	1.69	7.44	25.52	12.70	2.01	7.44	1751.00	68.62	0.10176	0.0959	254.54	0.00	0.56	6.53
1200	162	16.00%	7.50	4.09	1.66	7.47	24.62	12.46	1.98	7.47	1751.00	71.13	0.11180	0.1068	243.86	0.00	0.54	6.91
1100	146	16.00%	7.50	4.00	1.64	7.48	23.94	12.28	1.95	7.48	1751.00	73.14	0.12029	0.1160	232.26	0.00	0.53	7.21
1000	130	16.00%	7.50	3.93	1.62	7.49	23.43	12.14	1.93	7.49	1751.00	74.74	0.12739	0.1238	219.88	0.00	0.52	7.45
900	114	16.00%	7.50	3.88	1.60	7.50	23.03	12.03	1.91	7.50	1751.00	76.03	0.13330	0.1303	206.84	0.00	0.52	7.64
800	98	16.00%	7.50	3.83	1.59	7.50	22.72	11.95	1.90	7.50	1751.00	77.07	0.13818	0.1357	193.27	0.00	0.51	7.80
700	82	16.00%	7.50	3.80	1.58	7.50	22.48	11.88	1.89	7.50	1751.00	77.91	0.14221	0.1402	179.25	0.00	0.51	7.93
600	75.5	6.50%	7.50	3.92	1.62	7.49	23.38	12.12	1.93	7.49	1751.00	74.90	0.12810	0.1352	165.73	0.00	0.52	7.47
500	69	6.50%	7.50	4.03	1.65	7.48	24.21	12.35	1.96	7.48	1751.00	72.34	0.11684	0.1225	153.49	0.00	0.54	7.09
400	63	6.00%	7.50	4.14	1.68	7.46	25.04	12.57	1.99	7.46	1751.00	69.93	0.10693	0.1119	142.30	0.00	0.55	6.73
300	57	6.00%	7.50	4.25	1.70	7.43	25.80	12.78	2.02	7.43	1751.00	67.87	0.09891	0.1029	132.01	0.00	0.57	6.42
		6.00%												0.0956				

Station	Invert	So	Dia	Y	A	B	A	P	R	T	Q	V	Sf	Sfavg	EGL	GL-Hv-A/B-	Y/D	Froude
200	51		7.50	4.34	1.73	7.41	26.49	12.96	2.04	7.41	1751.60	66.11	0.09237		122.44	0.00	0.58	6.16



Client	Waste Management	Project	070181	Page	1/4
Subject	Waimanalo Gulch	Date	Nov. 13, 2009	By	AT
		Checked	Nov. 23, 2009	By	lgs.
		Approved		By	

Western Surface Water Drainage Project

Hydraulic calculations Flip-Bucket

Client	WM	Project	Page 1
Subject	FLIP BUCKET DESIGN	Date	Nov 13/09
		By	spalbar
		Checked	By
		Approved	By

TERMINAL STRUCTURE

From hydraulic calcs.

$$Q_{25} = 1135 \text{ cfs}$$

$$V = 55.25 \text{ /sec}$$

$$d/D = 0.57$$

$$D = 7.0 \text{ ft}$$

$$F = 5.68$$

Rotation angle $\Delta = 55.38^\circ$

Invert EL 81.89'

REF. USBR ENGINEERING MONOGRAPH No. 25

Client

Subject

Western Drainage

IMPROVED TUNNEL SPILLWAY FLIP BUCKETS

203

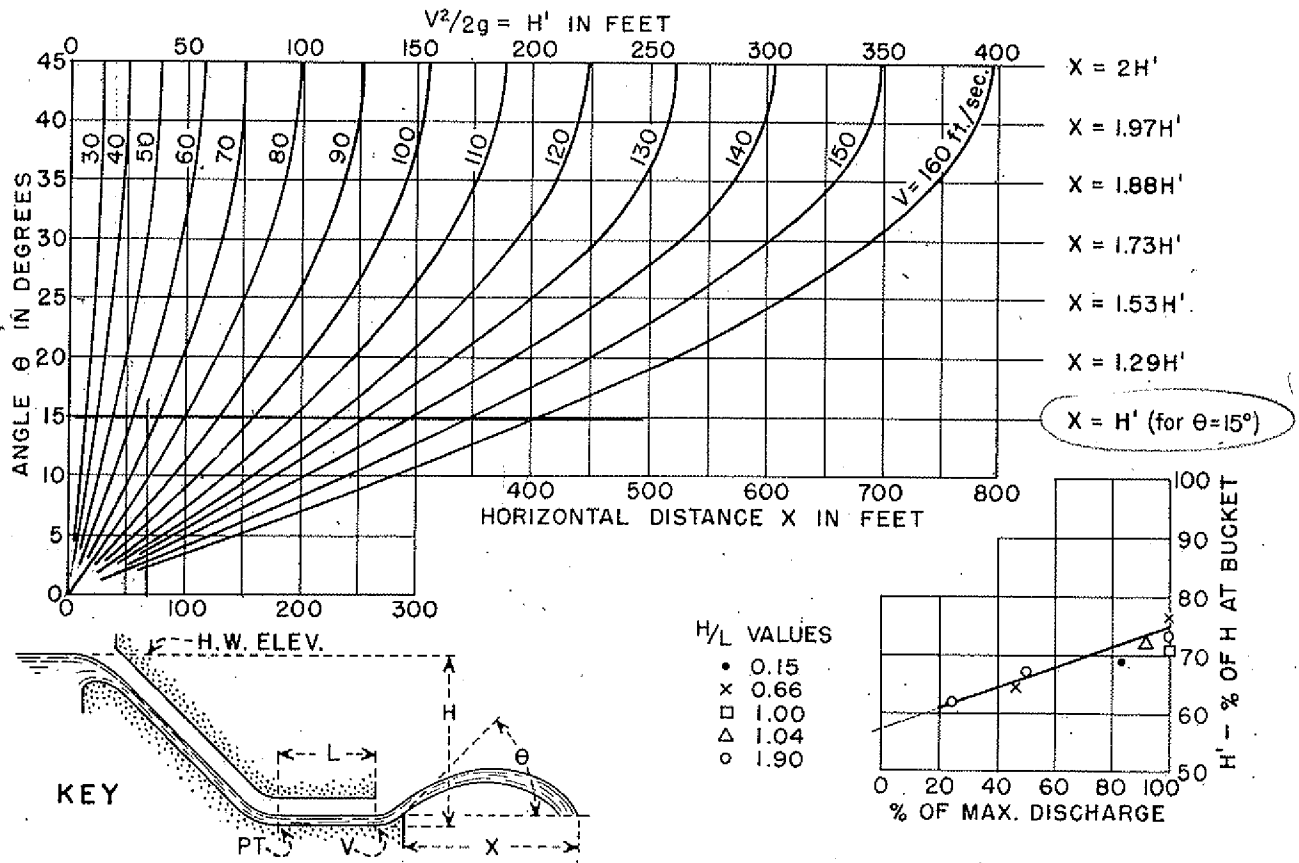


FIGURE 160.—Trajectory lengths and head loss.

$H' = 47.40'$ $X \approx 48'$